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Instream Biological Assessment Monitoring Protocols: *Benthic Macroinvertebrates*

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Instream Biological Assessment Monitoring Protocols: *Benthic Macroinvertebrates*

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INTRODUCTION

Purpose of this Document

This document describes Washington State Department of Ecology's Freshwater Ambient Biological Assessment Program. Outlined within the document is: 1) the sampling design, 2) the site selection process, 3) field implementation, 4) laboratory processing of data, and 5) analysis and interpretation of data that will be used in conducting this program. The document also includes all of the elements necessary to serve as a Quality Assurance Project Plan (QAPP) to guide the project.

Background

The Federal Clean Water Act (Section 101) mandates the development of water management programs that evaluate, restore, and maintain the chemical, physical, and biological integrity of the Nation's waters (U.S. EPA, 1990). Traditional measurements of chemical and physical components of rivers and streams do not provide sufficient information to detect or resolve all surface water problems. Biological evaluation of surface waters provides a broader approach because degradation of sensitive ecosystem processes are more frequently identified. Biological assessments supplement chemical evaluation by:

a) directly measuring the most sensitive resources at risk,
b) measuring a stream component that integrates and reflects human influence over time, and
c) providing a diagnostic tool that synthesizes chemical, physical, and biological perturbations (Hayslip, 1993).

Biological assessment in Washington State has historically been used on a project-specific basis. Stream impacts have been documented using an upstream/downstream approach at specific facilities (*i.e.*, industrial and wastewater treatment plants), or as a regional project to evaluate sampling and analytical protocols (e.g., Plotnikoff, 1992).

Ambient biological assessment of rivers and streams was initiated by the Washington State Department of Ecology (Ecology) in summer 1993. Condition of stream biology throughout the state has not previously been defined. This project is being conducted to consistently and comprehensively determine biological integrity in stream macroinvertebrate communities.

Purpose for Monitoring Stream Biology

Failure to demonstrate conservation and protection of water quality in the United States has prompted alternative directions for evaluating the resource. The continued decline in diversity of aquatic species throughout North and South America attests to the urgency with which conservation of our water resources must be addressed (Allan and Flecker, 1993). Maintenance of <u>biological integrity</u> was defined by Karr and Dudley (1981) as:

> "a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region."

Karr (1991) examined some of the reasons why evaluation of aquatic resources has taken so long in employing biological information. He also provided examples of how biological assessment of running water is applied in environmental evaluation and how powerful a tool this method is. Inclusion of multiple levels of biological measures (e.g., community structure and function, bioassays, tissue analysis, biomarkers) enhances the ability for accurately diagnosing the source of degradation.

The Washington State Department of Ecology (Ecology) recognizes the need for monitoring additional components of the ecosystem that are more sensitive to human influence and degradation than traditional monitoring activities have detected. Societal awareness for environmental quality has placed increased pressure on efficient regulation of natural resources. Stewardship of these resources requires us to apply the most effective evaluation techniques available. Our biological database is comprised of continuous monitoring information that describes the condition of aquatic resources in greater detail. The biological information is also used to confirm or validate interpretations derived from chemical and physical monitoring programs.

Ambient Biological Assessment Monitoring

The Ecology Ambient Biological Assessment Monitoring objectives are:

- to define and document <u>baseline</u> conditions of instream biology, and
- to measure <u>spatial</u> and <u>temporal</u> variability of population and community attributes.

Biological monitoring focuses on wadeable stream reaches at middle to upper locations in watersheds. Biological assessment effectively describes water quality and physical impacts from broad scale land use changes caused by forest practices, agriculture, and urbanization.

<u>Long-Term Ambient Monitoring</u>

The primary goal of the Freshwater Ambient Biological Assessment Program is to collect long-term information to refine knowledge of stream conditions. Long-term (multiple year) data are critical for providing measures that will describe typical interannual variability and define reference conditions. Environmental conditions (e.g., climate, intensity of natural disturbance) vary between years and subsequently influence stream biological communities. A key step in differentiating natural environmental influences from anthropogenic influences is to measure interannual variability.

Reference conditions are especially important in developing biologically meaningful criteria to protect resources. The reference condition reflects biological community potential in a stream, and is also used to describe spatial and temporal trends. But to be effective, biological criteria should reflect the variety of natural conditions that occur within a set of similar stream types. This is best achieved through long-term monitoring of reference and degraded sites.

Applications for Stream Biology Information

Ecology can currently use stream biological information to supplement the Statewide Water Quality Assessment Report (Section 305(b) of the Federal Clean Water Act), to prioritize streams/rivers for intensive surveys and development of total maximum daily loads (TMDL's, Section 303(d) of the Federal Clean Water Act), and to assess the success of pollution abatement programs (Section 319 of the Federal Clean Water Act). Over a longer term, stream biological information will support development of narrative (and eventually numerical) biological water quality criteria.

Many federal agencies and local governments also need stream biological information. New mandates for federal agencies such as the U.S. Forest Service, Bureau of Land Management, U.S. Geological Survey, and the U.S. Fish and Wildlife Service require them to evaluate the present condition of water resources within their jurisdictions. These biological evaluations assist in management decisions to preserve existing sensitive fish and wildlife populations and to restore water resources to their potential. A pre-existing baseline of stream biological information is also very helpful for local governments in implementing water quality and stream habitat improvement programs.

PROJECT ORGANIZATION

Personnel

Field work is completed with at least two personnel who gather samples and measure physical variables at each site. The project leader designs and directs the components of the biological assessment program. A junior scientist or environmental technician collects biological and physical data from rivers and streams, performs laboratory sample sorting and taxonomic identifications, and records data in a database.

Experience

The Senior Scientist must be able to: 1) independently design a project and direct field work, 2) identify most benthic macroinvertebrate taxa to species, with available taxonomic literature, 3) understand and apply current stream ecology theory for interpretation of the biological data, 4) operate a variety of computer software including word processors, spreadsheets, statistical programs, and databases, and 5) supervise more junior personnel. Qualifications for the junior scientist/environmental technician are: 1) ability to understand project design and implement the components, 2) efficiently use taxonomic keys and identify most taxa to genus,

3) have a general knowledge of computer software operation, and 4) to operate stream sampling equipment for measuring biological communities and physical variables.

STUDY DESIGN

Sampling Strategy

General Design

This program uses representative multiple-habitat sampling of benthic macroinvertebrates and physical habitat to describe biological community condition as a result of natural and anthropogenic disturbance. To distinguish natural versus anthropogenic influence, data must be collected at reference sites and at impacted sites over a period of time to address interannual variability.

Reference sites are intended to represent one of two reference stream conditions: 1) relatively unimpacted, or 2) least impacted. Relatively unimpacted conditions reflect sites that have experienced very little historical activity that alters stream integrity. Least impacted sites had been degraded historically, but have exhibited some level of recovery. Reference sites are used to describe biological variability due to natural disturbances (*i.e.*, precipitation, drought).

Impact sites are intended to describe the gradient of human influence on natural stream communities. Identification of what a degraded macroinvertebrate community is and the factor(s) that caused the resulting condition defines severity of impact. This gradient of biological conditions is used to determine the levels of anthropogenic disturbance that are excessive in a waterbody.

The biological community in rivers and streams represent an important source of information when evaluating ecological integrity. We use a single biological component, the benthic macroinvertebrates, to evaluate stream condition. Evaluation of the fish community is not used as a sole source of information because of species paucity in western North America (Moyle and Herbold, 1987). Aspects of fish community evaluation will be considered in future work.

Long-term biological conditions are addressed by monitoring at "core" sample stations. Each ecoregion is monitored annually at one or two core sites. The remaining sample stations are represented by "rotating" sites. Location of the rotating sites are directed by the range of conditions represented within the watersheds of focus during that year. Approximately 20 to 30 rotating sites are monitored annually.

Sample Site Selection Criteria

Sample sites are selected non-randomly. Core and rotating sites will be targeted to sample the best reference conditions and the most representative impacted conditions in the following geographical locations:

- regional basins/watersheds scheduled for a monitoring focus in the current year
- the range of defined ecoregions within basins
- representative land uses and associated impacts
- sites where both legal and physically practical access can be obtained.

Physical differences among the sample sites are an unavoidable result of inherent regional variability. The total number of sites sampled annually will be determined by logistical constraints such as personnel, field time, and laboratory analysis.

Regional Basins/Watersheds

In 1993, Ecology initiated a watershed approach to water quality management (Appendix A). Priority basins scheduled for discharge permit issuance are monitored three years in advance. Permit issuance and their timing guide monitoring activities. The five step process used prior to discharger permit approval includes: scoping, monitoring, analysis, planning, and permitting. Scoping refers to identifying the focus for project work within a watershed. Monitoring of waterbodies within the watershed follows with subsequent analysis of the collected information. Planning entails strategies to abate pollution problems in the watershed and this information becomes useful in guiding permitted effluent discharges. This cycle of activities requires five years to complete with monitoring occurring two to three years prior to permit issuance.

Each year, several streams from each of the focus basins will be chosen to represent prevailing biological conditions. Sites will be selected according to location of the reference condition, and according to the representative dominant land use impacts on stream biotic communities. Where reference conditions within a drainage can not be located, those conditions must be inferred from similar streams within the same ecoregion (see below). Current sample site locations for biological assessment are found in Appendix B.

Ecoregion Representation

Ecoregions are geographical regions of relative homogeneity either in ecological systems or involving relationships between organisms and their environment (Omernik and Gallant, 1986). Mappable characteristics are used to define these regions of relative homogeneity which include: land surface form, potential natural vegetation, land use, and soils. We use the U.S. Environmental Protection Agency's defined ecoregions (Omernik and Gallant, 1986).

Information from sample sites will be extrapolated to other similar streams within an ecoregion framework. It is, therefore, important to represent the variety of stream conditions within ecoregions to compare results measured by this program. Regional biological description will be defined by including information from reference sites (least or relatively unimpacted conditions), sites recovering from historic impact, and visually degraded sites.

Washington State is comprised of eight ecoregions: Coast Range, Puget Lowland, Cascades, Columbia Basin, Northern Rockies, Willamette Valley, Blue Mountains, and Eastern Cascade Slopes and Foothills. Specific community characteristics are the focus of data analysis which explore intra-regional variability within any one year and inter-annual variability over five years. Intra-regional variability describes the range of biological community conditions expected spatially. Inter-annual variability attempts to identify the influence of cyclic environmental conditions on biological communities such as: annual precipitation patterns or ambient air temperature. Long-term benthic monitoring sites are used as a calibration tool to measure the relative stream condition of basin or near-field sampling sites.

<u>Representative Land Uses</u>

Stream sample sites that have a gradient of land-use influences are annually chosen for monitoring in at least two ecoregions. The type of land use within an ecoregion influences biological communities and these relationships are described with independent stream surveys. Dominant land use within priority basins and ecoregions is initially determined. A visual estimate of the severity of land use is made to ensure that sites are chosen to represent a gradient of human influence. This hypothetical impact gradient is further validated when field information is analyzed as described in a subsequent section of this document. Sampling and analysis of degraded stream reaches has a two-fold purpose:

- to validate acceptable reference condition delineation; and
- to determine the sensitivity of biological impact detection.

Quantifying land uses within a watershed is the initial step used in analyzing the current biological community condition. Land use is determined within a 100 meter wide buffer along both sides of the stream. The buffer encompasses all areas of the catchment upstream of the sample reach.

The land use coverage currently available is Anderson *et al*. (1976). More current land use coverages will be used as the data become available. The following list details the land uses represented in the current analysis:

Residential	Industrial
Commercial and Services	Transportation, Communications, Utilities

Mixed Urban or Built-Up Land
Other Urban Land
Agricultural
Cropland and Pasture
Orchards, Groves, Vineyards, and Nurseries
Confined Feeding Operations
Other Agricultural Land
Herbaceous Rangelend
Shrub and Brush Rangeland
Mixed Rangeland
Deciduous Forest Land
Evergreen Forest Land
Mixed Forest Land

(Appendix B, Sample Site Location Map)

Lakes
Reservoirs
Bays and Estuaries
Forested Wetland
Nonforested Wetland
Beaches
Sandy Areas Other Than Beaches
Bare Exposed Rock
Strip Mines, Quarries, and Gravel Pits
Transitional Areas
Mixed Barren Land
Shrub and Brush Tundra
Herbaceous Tundra
Bare Ground Tundra
Wet Tundra
Mixed Tundra
Perennial Snowfields
Glaciers

Index Period

An index period is a time period during which samples are collected. The index period in 1993 (August-October) was chosen with the following criteria:

- adequate time for the instream environment to stabilize following natural disturbances (*i.e.*, spring floods)

- representation of benthic macroinvertebrate species reaches a maximum, particularly during periods of pre-emergence (typically mid-spring to late-summer).

This sampling window is characterized by general hydrologic characteristics such as high flow/flood conditions (e.g., active sediment transport), low flow/stress conditions (e.g., high water temperatures deleterious to macroinvertebrate species), or by the appearance of large numbers of macroinvertebrate species (typically spring season). Biological assessments can yield different interpretations depending on the index period chosen. This is because natural seasonal disturbances and physical stream conditions strongly affect the diversity, abundance, and life stage progression of aquatic insects (Hynes, 1970; Vannote *et al*., 1980).

DATA QUALITY OBJECTIVES

Precision

Total precision will be estimated from the results of four replicate samples collected from 10% of the reaches sampled annually in the riffle habitats. Depositional habitat is not examined for sampling precision estimates. The goal for coefficient of variation (CV) from four replicate riffle samples is ≤ 20% when using the taxa richness metric (Plotnikoff, 1992). We expect collections of macroinvertebrates from four sample locations to have similar community structure.

Bias

Correct identification of benthic organisms is important for definition of community structure and function. Taxonomic misidentification results in inadequate stream biology characterization. Errors in identification of benthic macroinvertebrate taxa should be ≤ 5% of the total taxa in the sample. Re-identification of samples are done for 10% of the total number of samples collected in each year. Secondary identification is conducted by experienced taxonomists in order to maintain confidence in the data set. A voucher collection is maintained by the Department of Ecology and is updated on an annual basis with macroinvertebrate specimens from each year's collection. All taxa are coded with the source for taxonomic literature used in identification.

Representativeness

Representativeness of benthic community conditions is determined by the sample program design (Lazorchak and Klemm, undated). The sampling protocol was designed to produce consistent and repeatable results per surveyed stream reach. Samples are collected equally from depositional and riffle areas of streams. Physical variability within each habitat type is accounted for by sampling in both deep and shallow locations within the sample reach.

Completeness

Completeness is defined as the proportion of useable data gathered (Ecology, 1991). Sample loss will be minimized with sturdy sample storage vessels and adequate labeling of each vessel. Sample vessel type and labeling information are described under "Sampling Techniques." Contamination of samples through careless handling will make the information for the station suspect. Sample contamination occurs when containers are improperly sealed or stored. Loss of benthic material or desiccation diminish the integrity of the sample. If the validity of the information from the sample is in question, the sample may be excluded from analysis. The goal for completeness of benthic macroinvertebrate data sets is 95% of the total samples collected. Completeness is defined as the total number of useable samples that we are confident in using for further data analysis following field collection.

Sampler and operator efficiency both influence completeness. One measure of sampler/operator efficiency is the number of taxa collected or "total taxa richness." The discrepancy between transects in the total number of taxa collected is attributed to sampler/operator efficiency (*i.e.*, the ease with which various species can be collected) and the distributional characteristics of benthic dwelling organisms. Some species are considered rare and may be difficult to collect due to low abundance or are difficult to sample in certain habitats.

Comparability

Comparability describes the confidence in comparing one data set to another. Many private, academic, and governmental entities are currently generating biological information for rivers and streams that could potentially be incorporated into a larger data set. Comparability of data sets is primarily achieved through adherence to commonly accepted protocols (e.g., field sampling, analytical methods and objectives). Our multihabitat collection approach using a D-frame kicknet was chosen largely to provide necessary comparability with Oregon Department of Environmental Quality's bioassessment program and the Environmental Protection Agency's "Regional Environmental Monitoring and Assessment Program" (R-EMAP).

SAFETY PROCEDURES

Field and Laboratory Preservatives

Biological samples collected from streams must be preserved immediately following storage in containers. Inadequate preservation often results in: 1) loss of prey organisms through consumption by predators, 2) eventual deterioration of the macroinvertebrate specimens, and 3) deformation of macroinvertebrate tissue and body structures making taxonomic identification difficult or impossible.

The field preservative used in this program is 85% denatured ethanol. The preservative is prepared from a stock standard of 95% denatured ethanol. Flammability, health risks, and containment information are listed on warning labels supplied with the preservative container. Detailed information can be found with the "Materials Safety Data Sheets" (MSDS) maintained by the Environmental Investigations and Laboratory Services Program Manager's Secretary. Minimal contact with the 95% denatured ethanol solution is recommended.

The preservative used in handling sorted laboratory samples is 95% ethanol (non-denatured). Seventy percent non-denatured ethanol is used for preservation of voucher specimens in two dram vials (8 mL). Hazard Communication Training is provided to all personnel that come into contact with hazardous materials while conducting program duties.

Miscellaneous

Field activities should be conducted by at least two persons, especially when in remote streams. A contact person should be designated at the headquarters office to which field personnel report daily at predesignated times.

Careful planning of field activities is essential and permission to access private land must be obtained. Access to private land is usually obtained through verbal agreement with the landowner while at the proposed sample site.

Special safety equipment includes:

- Felt Soles <u>or</u> Cleats (for waders)
- Rain Gear
- Insulated Rubber <u>or</u> Neoprene Gloves
- First Aid Kit (stored in the vehicle)
- Department of Ecology Photographic Identification Card
- Certification in CPR/First Aid

FIELD OPERATIONS

Macroinvertebrate Sampling

<u>Sampling Techniques</u>

At each site, stream reach length is determined by identifying the lower end of the study unit and estimating an upstream distance of 40 times the stream width. The lower end of a study unit is randomly located at the point of access to the stream and is always below the first upstream riffle encountered. The stream reach length should measure approximately 150 meters if stream width is narrow (< 3 meters). This reach length ensures that characteristic riffle/pool sequences are represented and potentially sampled.

The sampling routine used at each site includes collection of surface water information and estimation of discharge at the furthest downstream portion of the sample reach. Collection of benthic macroinvertebrate samples follows the initial surface water chemical and physical measurements. The last component of a site visit is habitat characterization. Thus stream disturbance is minimized before the biological information is collected.

Locations of macroinvertebrate sample sites within the reach are determined through careful identification of four riffle areas and four depositional zones. A variety of riffle and depositional sites are chosen within the reach to ensure representativeness of the biological community. Ideally, riffle samples should include collection from two shallow-fast habitats and from two deep-fast habitats. The D-frame kicknet (500 micrometer net mesh) is used to collect four composited samples from each riffle and four composited samples from each slackwater zone (run or pool, where present). Ten percent of the replicate riffle samples collected this year were stored in separate containers. The stream area sampled is thoroughly disturbed a distance of two feet directly upstream of the D-frame kicknet opening. Every removable rock is scrubbed by hand in the 1 foot x 2 foot sample area. A leaf litter sample (also known as CPOM=coarse particulate organic matter) is also collected from the stream reach. Leaf litter is gathered from a minimum of two depositional locations and should include decayed and newly deposited material. Twigs, sticks, and aquatic plants may be sampled in the absence of leaf debris.

The composited macroinvertebrate field samples are preserved in 85% ethanol. Storage containers can either be heavy duty Ziploc® freezer bags or one liter Nalgene® containers. A double bag system is used when storing samples in freezer bags. Sample labels are placed in the dry space between the inner- and outer freezer bags. Label information should contain: name of stream (including reach identification), date of collection, preservative used, project name (if applicable), type of sample (*i.e.*, macroinvertebrate, leaf litter, etc.) and collector's name. Sample containers can be assigned an identification number when stored in the laboratory. Additional physical and chemical stream information is associated with the numbered biological collections in the database.

Habitat Survey

The physical characteristics of instream and riparian areas of streams have a substantial influence on the structure and function of benthic macroinvertebrate communities. Habitat characterization is used concomitantly with biological assessment surveys to: 1) understand the natural physical constraints imposed on macroinvertebrate communities, and 2) detect physical changes within sensitive stream areas and adjacent riparian zones. Habitat measurements can be divided into two categories: 1) site-specific, detailed instream measurements, and 2) riparian and upstream watershed disturbance (land-use type and intensity).

Habitat Variables

An aggregation of qualitative (visual) and quantitative instream habitat characteristics are assessed. Site specific habitat features that limit biological conditions and that produce repeatable results are measured. Quantitative variables are measured where benthic macroinvertebrates are collected. This survey differs from reach characterization of physical habitat by focusing on site-specific conditions that influence the collected macroinvertebrates. Other instream physical conditions are best measured as presence/absence and are efficiently assessed with qualitative methods.

Habitat measures used in this monitoring program are listed below:

I. Reconnaissance Surveys

1. Valley Segment Classification
    i) channel pattern
    ii) valley bottom slope/sideslope gradient
    iii) valley bottom width
    iv) channel adjacent geomorphic surfaces

2. Riparian Vegetation Structure
    i) canopy
    ii) understory
    iii) ground cover

II. Individual Site Visits

3. Stream Reach Profile
    i) maximum depth
    ii) wetted width
    iii) residual pool depth
    iv) bankful width
    v) stream gradient

4. Canopy Cover
    i) center of stream readings
    ii) left bank/right bank readings
    iii) percent solar radiation (solar pathfinder)

5. Substrate Characterization
    i) percent fines
    ii) substrate embeddedness
    iii) substrate composition (general description)

6. Large Woody Debris
    i) size/length
    ii) decay class
    iii) % in water
    iv) structural configuration

The six general physical habitat categories describe influential attributes that affect the benthic macroinvertebrate community. The components for each habitat category were chosen to describe the extent to which physical factors influence the dependent biological community. The following hypotheses were considered when choosing the physical features measured at each sample site:

1. Valley Segment Classification:
   A landscape stream typing classification may be one strategy that associates similar macroinvertebrate community groups.

2. Riparian Vegetation Structure:
   The quantity and type of riparian vegetation influences the functional attributes of the macroinvertebrate community. Allochthonous macroinvertebrate food sources are determinants for the presence of secondary consumers.

3. Stream Reach Profile:
   The morphological characteristics of a stream reach influence the potential severity of natural disturbance effects. High flow periods of the hydrograph can have considerably reduced effects on the biota when stream morphology dissipates water energy.

4. Canopy Cover:
   Physical variables such as temperature and dissolved oxygen in the water column are influenced by solar radiation that reaches the stream surface. Autochthonous macroinvertebrate food sources (*i.e.*, periphyton) are directly influenced by quantity of overhead canopy.

5. Substrate Characterization:
   Heterogeneity in stream substrate promotes taxa rich communities. Increased substrate embeddedness reduces the available habitable areas for macroinvertebrates.

6. Large Woody Debris:
   Presence of woody debris facilitates, in part, the stability of the stream channel during high flow periods. Woody debris also provides habitable substrate for macroinvertebrates and cover for fish.

The qualitative habitat survey conducted in this biological assessment program is adapted from the modified U.S. Environmental Protection Agency Region 10's Riffle/run habitat assessment (Hayslip, 1993). The assessment effort is limited to visual surveys that provide categorical information. Individual site habitat survey scores are compared to defined regional reference site conditions. The comparison is expressed as a percent of the expected reference habitat condition. Habitat categories included in the qualitative assessment indicate general physical changes of the instream and riparian environment.

Stream biology is the focus for analysis of ecological integrity. The habitat variables measured provide a frame of reference from which to compare multiple stream sites that are surveyed. Analysis of the benthic macroinvertebrate community will tell us about the ecological integrity of a stream while the habitat variables provide some insight to increasing stream integrity through our management decisions. A comprehensive description of qualitative and quantitative habitat characterization methods is located in Appendix C.

Watershed Land Use Survey

Both visual riparian surveys and watershed geographical information system (GIS) coverages are used to assess human influence and/or potential degradation on stream benthic communities. GIS coverages are obtained from existing databases that may be out of date and are ground-truthed during the reconnaissance surveys at a site. Laboratory activity involving GIS includes digitizing a buffer around the watershed that is situated above a sample reach. Representative land use categories are described in a previous section. Land-use information is a large-scale measure that we attempt to relate to benthic community condition. The objective for exploring these relationships is to create a predictive tool for impact expectations if land use intensifies within a watershed.

Surface Water Monitoring

Surface water analysis is limited to four field variables that are also routinely measured in most of the Agency's projects: temperature, pH, dissolved oxygen, and conductivity. Additional observations include: water clarity, water/sediment odors, and surface films. Measurement of all surface water variables are made before biological samples are collected from the reach.

Water Quality Analyses

Water samples are collected directly from the lowest portion of the sample reach and transported back to the vehicle for measurement as quickly as possible. The following instruments and methods are used to measure surface water values:

Parameter	**Method**	**Detection Limit**
Temperature	YSI Thermistor	± 0.1°Centigrade
pH	Orion, Model 250A	± 0.1 pH Units
Conductivity	YSI Conductivity Meter, Null Indicator	± 2.5 µmhos/cm @ 25°C
Dissolved Oxygen	YSI Membrane Electrode, Model 57	± 0.2 mg/L
	or Winkler Titration	± 0.1 mg/L

Quality Assurance

Replicate water quality measurements are made for one of five sample sites visited. Bias is determined by comparing instrument readings with solutions of known concentration (*i.e.*, buffers for pH, conductivity standard, and calibration of the thermometer). Comparability is assured by using standard procedures.

LABORATORY SAMPLE PROCESSING

Benthic Macroinvertebrate and CPOM Samples

The depositional and riffle samples collected at each site are sub-sampled using a 300 organism count. Macroinvertebrates are removed from a minimum of two randomly chosen squares in a sub-sampling grid containing 30 squares. The dimension of each square is 6 cm x 6 cm and the tray has an overall dimension of 30 cm x 36 cm. The sample material from a field container is spread evenly on the base of the grid tray. The assumption of sub-sampling is that the procedure is random and unbiased. All organisms are removed from randomly chosen squares until a minimum of 300 macroinvertebrates are picked and the process is continued to include all remaining organisms in the selected squares. Larger macroinvertebrates are removed from the sample square prior to use of a magnification device such as a dissecting scope or a hand-held magnifier. In most cases, greater than 300 macroinvertebrates are sub-sampled using this procedure.

Depositional and riffle samples remain in separate containers following the sub-sampling procedure. In cases where the four riffle sample replicates from a site are in separate field containers, separate laboratory storage containers are used for organisms sub-sampled. All sub-sampled macroinvertebrates are placed in 70% ethanol that is prepared from a stock solution of 95% non-denatured ethanol. Leaf material or the "CPOM" (coarse particulate organic matter) sample is cursorily examined for predominant organisms. Presence/absence information obtained from the CPOM sample may be used to indicate the quality of detritus accumulated within the site reach. In cases where CPOM is found in depositional samples, the CPOM sample is not sorted and further analyzed.

Benthic Macroinvertebrate Identification

All major Orders of freshwater macroinvertebrates are identified to at least the generic level and to species where existing taxonomic keys are available. Each taxon has an associated source key used for the identification so that future revision of macroinvertebrate taxonomy will be easily incorporated into the database. Taxa groups normally identified to coarser taxonomic levels include: Chironomidae, Simuliidae, Lumbriculidae, Naididae, select families of Coleoptera, Planariidae, and Hydracarina (suborder). The following list represents the major taxonomic keys used to complete taxonomic identification:

- (Merritt and Cummins, 1984) An Introduction to the Aquatic Insects of North America

- (Pennak, 1978) Freshwater Invertebrates of the United States

- (Usinger, 1963) Aquatic Insects of California with keys to North American genera and California species

- (Edmondson, 1959) Freshwater Biology

- (Needham *et al.*, 1935) The Biology of Mayflies

- (Edmunds *et al.*, 1976) The Mayflies of North and Central America

- (Jensen, 1966) The Mayflies of Idaho (Ephemeroptera)

- (Baumann *et al.*, 1977) The stoneflies (Plecoptera) of the Rocky Mountains

- (Stewart and Stark, 1989) Nymphs of North American Stonefly genera (Plecoptera)

- (Wiggins, 1977) Larvae of the North American caddisfly genera (Trichoptera)

- (McAlpine *et al.*, 1981) Manual of Nearctic Diptera, Volume 1

- (Burch, 1982) Freshwater Snails (Mollusca: Gastropoda) of North America

Additional literature is used to confirm distributions and variations in characteristics of individual taxa. Descriptions of biology are used to confirm likely distributions, particularly when larval or nymphal forms of macroinvertebrates are difficult to identify.

Laboratory Quality Assurance

<u>Macroinvertebrate Sorting</u>

Precision of the sub-sampling process is evaluated by resorting a sub-sample of the original samples. Ten percent of the benthic macroinvertebrate samples are resorted by a second investigator. Half of these resorted samples are from depositional areas and the remaining half are those collected from riffle habitat. Discrepancies between sorting results indicates the need for:

1) more thorough distribution of sample materials in the sub-sampling tray,
2) special attention given to easily missed taxa when sorting (*i.e.*, use of a magnifier).

There is no re-evaluation of the CPOM sample sorting for each of the sites. The CPOM samples are used only as a qualitative descriptor.

Macroinvertebrate Identification

Verification of taxonomic identification is completed for ten percent of the samples collected annually. Sub-samples may be provided to qualified taxonomists at the Oregon Department of Environmental Quality Laboratory (Portland, Oregon) or the Idaho Department of Health and Welfare - Division of Environmental Quality (Boise, Idaho) for re-identification. Difficult taxa are sent to museum curators whose specialty includes members of a particular Order. Site samples that are re-identified correspond with the sites used to evaluate the sub-sampling procedure.

DATA ANALYSIS

General Analytical Procedures

Graphical relationships are constructed by using individual qualitative or quantitative independent variables versus the dependent biological metric or index variables. Strong relationships between physical and biological variables frequently suggest controlling or limiting factors at streams on some spatial scale (e.g., ecoregions, watersheds). The strength of a physical/biological relationship is determined visually from the graph and is a relative evaluation based on performance of all variable pairs.

Biological Metrics

Several methods for describing macroinvertebrate assemblages can be used to define stream biological condition. The attributes or metrics provide detailed information regarding the trophic status and structural aspects of the community. Each of the metrics is used as a component of a diagnostic tool that defines ecosystem condition. A host of indexes and metrics have been proposed, but the following list contains those that are directly applicable to the Pacific Northwest:

- Species Richness:
  total number of species in the sample

- Modified Hilsenhoff Biotic Index:
  community tolerance to nutrient enrichment (Hilsenhoff, 1977; 1982; 1987)

- Biotic Condition Index (BCI):
  tolerance to chemical and physical instream conditions (Winget and Mangum, 1979)

- Benthic Index of Biological Integrity (B-IBI):

based on consistent biological metric performance (Kerans *et al.*, 1992)

- EPT Index:
  presence of sensitive taxa (Ephemeroptera, Plecoptera and Trichoptera)

- Relative Abundance:
  macroinvertebrate abundance estimate per unit area

- Ephemerellidae & Heptageniidae Richness:
  higher number of species generally indicate greater habitat complexity

- Caddis & Stonefly Shredder Richness:
  shredder taxa tend to disappear as stream habitat complexity and retention capacity decline (Wisseman, 1993)

- Rhyacophilidae Richness:
  higher number of species generally indicate greater habitat complexity (Wisseman, 1993)

- % Contribution of Dominant Taxon:
  greater dominance by a single taxon usually indicates a stressed community

- % Predators:
  indicators of stressed conditions in montane regions (Wisseman, 1993)

- % Shredders:
  indicate good stream retention capabilities of organic matter and the quality of the allochthonous input

- % Scrapers:
  indicate the presence and quality of primary productivity (periphyton)

- % Collector-gatherers:
  indicative of stressed stream conditions that have experienced greater accumulations of fine particulates

- % Collector-filterers:
  greater numbers indicate the presence of increased quantities of fine suspended particulates

- % Intolerant Mayfly & Caddisfly & Stonefly:
  % representation is high where stream integrity remains good

- % Glossosomatidae:

representation of these taxa is poor where sediment impacts and nutrient enrichment occur

- % Hydropsychidae:
  greater representation is indicative of a general decline in water and habitat quality

- Voltinism (life cycles: annual, semi-annual, multi-annual):
  indicates the presence and intensity of natural and anthropogenic stream disturbances

Ordination: Identifying Unique Ecosystem Functions

Analysis of biological conditions at individual sites will not usually reveal unique hydrologic functions that occur in a watershed (e.g., periodic drought, underground spring influence). Simultaneous comparison of multiple sites within a logical regional framework (*i.e.*, ecoregions) identify which sites appear to be different based on their biological composition. Macroinvertebrate assemblages can also be differentiated based on the effects of stressors when using ordination (Lewis, 1993).

Graphical spatial characterization of sites using similarity of biological communities is an ordination technique known as Detrended Correspondence Analysis (DCA). The species by site matrix used in DCA is transformed using the $\{\log_{10}(x+1)\}$ function before being analyzed (Hill, 1979a). The transformation eliminates zero abundance values within the matrix that will otherwise receive unequal weight in ordination analysis (Gauch, 1982; Zar, 1984). TWINSPAN, or two-way indicator species analysis (Hill, 1979b), also provides site similarity information in addition to defining distinct taxa groups. This ordination analysis provides a general view of any continuities that exist among the sampled sites.

Land-Use (Geographical Information Systems)

The initial phases of data analysis compare land use with biological attributes within upstream locations in the watershed. An example would be the comparison of the "percentage of a forested watershed that was harvested" versus "intolerant aquatic insect species" which is usually represented by a suite of taxa belonging to the mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera). Results are then used to extrapolate the potential for impacts to streams in other similar watersheds. A variety of combinations of land use attributes and biological community metrics will be compared to describe prevailing land use influences on instream organisms. The process begins with the identification of prevalent land uses in a region, and the detection of impacts associated with each type. This is a descriptive exercise that has future application for selecting sites that represent a gradient of human influence.

Historically, biological assessments were hampered by the focus on measuring species abundance and population size. However, this problem can be addressed by sampling and analytical approaches designed to concentrate on more relevant and less variable biological attributes than populations (Klemm *et al.*, 1990). These include:

1) application of a consistent, repeatable sampling protocol,

2) description of reference conditions through a meaningful spatial framework,

3) employing a variety of metrics that measure community attributes (rather than measures of species abundance).

Data analysis begins with calculating a variety of community metrics. These can be rank ordered to display gradients in stream condition, used in ordination techniques to define (quantitatively) clusters of stream conditions, or directly compared between reference and non-reference sites. The degrees of confidence that can be applied to these measures is increased when:

1) numerous, different metrics consistently rank for a given site of interest,

2) relative ranking at different sites remains consistent over time (between years),

3) rankings relate to observed land uses or significant human influence.

A number of states (*i.e.*, Ohio, North Carolina) have successfully used this approach to support narrative or numerical biological criteria used in regulatory efforts (Ohio EPA, 1988; NC Division of Environmental Management, 1992).

<u>Similarity to an Indicator Assemblage</u>

Groups of benthic macroinvertebrates were previously defined as indicator assemblages for three ecoregions in Washington: Puget Lowland, Cascades, and Columbia Basin (Plotnikoff, 1992). A comparison of the summer 1993 macroinvertebrate collections to previously defined regional assemblage expectations is evaluated. The revision or refinement of the current taxa list is a primary objective for this comparison.

<u>Trend or Temporal Analysis</u>

Reference conditions described in the Timber, Fish, and Wildlife Ecoregion Bioassessment Pilot Project (Plotnikoff, 1992) can be validated through surveys of nine sites resurveyed in 1993. Four of the sites re-surveyed are located in the Cascades ecoregion and five of the sites were re-surveyed in the Columbia Basin ecoregion. The initial bioassessment survey for each of the sites occurred in August 1991. The re-surveyed sites are:

American River (Yakima County)

Middle Fork Teanaway River (Kittitas County)
Naneum Creek (Kittitas County)
Umtanum Creek (Kittitas County)
Cummings Creek (Columbia County)
North Fork Asotin Creek (Asotin County)
Little Klickitat River (Klickitat County)
Trapper Creek (Skamania County)
Entiat River (Chelan County)

Temporal variability between bioassessment surveys conducted in summer 1991 and summer 1993 will be analyzed. Four Cascade reference streams define biological conditions from both years. Five Columbia Basin streams define biological conditions for summer 1991 and 1993. Activities within upstream drainage areas of each sample site are compared for shifts of land use and intensity.

DATA MANAGEMENT

Current Data Management Procedures

A Paradox® database system was developed for use in the Timber, Fish, and Wildlife Ecoregion Bioassessment Pilot Project (Plotnikoff, 1992). The database was structured to upload data to U.S. EPA's BIOS component of STORET. Three components to this database were used to record chemical, physical, and biological information (Appendix D). Key fields within each database component allow simultaneous information queries from multiple files. The key fields used to link the chemical, physical, and biological files are: <u>Ecoregion</u> and <u>Station</u>.

A similar data management system is used in the current Ambient Biological Monitoring Program. Alterations of the original T/F/W Bioassessment database will be most substantial in the habitat component and will provide an abbreviated form of the original chemical component. The macroinvertebrate database that was used in prior programs will remain intact.

Compatible Databases

The database used in the Ambient Biological Monitoring Program contains fields that are required by BIOS (U.S. Environmental Protection Agency STORET). Additional fields are included in the database that facilitate information retrieval for partitioning of data sets. The biological database does not incorporate metric information because of the reduction in data storage capacity. Data is typically exported in Lotus 123® format or as an ASCII file for analysis.

Common databases used by State and Federal Agencies incorporate DBase in their data storage strategies. DBase (all versions) is one of the preferred export formats of Paradox® version 3.5. U.S. Environmental Protection Agency Region 10 Office is currently developing a database for their Regional Environmental Monitoring and Assessment Program (R-EMAP). The benthic macroinvertebrate component of the R-EMAP database is currently available and includes the following fields:

* ECOREGION:	
* STATION:	
* DAY:	
* MONTH:	
* YEAR:	
* SEASON:	
* ORDER:	
* FAMILY:	
* GENUS:	
* SPECIES:	
SPEC_CODE:	DECORANA/TWINSPAN species abbreviation
* CIC:	
* ABUND:	Number of organisms in sub-sample
PCT_ABUND:	Percent Abundance
* TOT_ABUND:	Total Abundance
* METHODTYPE:	
* SAMPLEAREA:	
* FFG:	Functional Feeding Group
TOT_TAXA:	Total number of taxa in sample
EPT_TAXA:	Total number of Ephemeroptera/Plecoptera/Trichoptera taxa
* TV:	Tolerance value for taxon
HBI:	Hilsenhoff Biotic Index score
PCT_SHRED:	Percent Shredders
FILE:	Filename if source file is different

The habitat database for the R-EMAP program is currently being developed and will contain many of the same components that the Ambient Biological Monitoring Program database maintains. Asterisks denote those variable fields that are compatible with the Ambient Biological Monitoring database.

REGIONAL ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM (R-EMAP)

Coordination with R-EMAP

The U.S. Environmental Protection Agency Region 10 Office is coordinating the R-EMAP project during the summers of 1994 and 1995 in the Coast Range Ecoregion of Washington State and Oregon. Collection of instream biological, physical, and chemical information will be completed at 30 stream sites in the Coast Range and at 15 sites in the Yakima River Basin. Site location is determined through a random selection process and is weighted to choose wadable 2^{nd}, 3^{rd}, and 4^{th} order streams.

The Ambient Biological Assessment Program (Ecology) has conducted only a few surveys in the Coast Range. The additional biological, chemical, and physical information that the R-EMAP project will generate for this ecoregion will be a valuable addition to Ecology's database. Field sampling techniques for both the R-EMAP program and the Ambient Monitoring Program are comparable. Multihabitat collection of benthic macroinvertebrates in riffle and depositional stream areas are consistent, as well, most of the habitat variables are measured using the same techniques.

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APPENDIX A

Washington State Department of Ecology:
Watershed Approach to Water Quality Management

An Overview of Washington State's Watershed Approach to Water Quality Management

Ron McBride, Watershed Coordinator
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In July 1993, the Washington State Department of Ecology initiated a new managerial framework to improve the **protection of water quality. Ecology began a five year** transition to a comprehensive Watershed Approach to Water Quality Management. In this approach, both point and nonpoint source problems and needs are addressed for all parts of the state.

As a management approach, the design was formulated to guide the organization toward improving coordination of water quality activities, service delivery, protection and prevention activities, and finally improved water quality statewide.

The cornerstones of the approach are the designation of water quality management areas (WQMA), the appointment of staff "leads" for each WQMA, and a five step process for systematically issuing permits, assessing water quality conditions, focusing staff effort, and developing an improved basis for decision making in 'each WQMA. This management model was necessitated by the need to increase protection using fewer resources. The objective is to develop more precise information so that managers can allocate scarce resources to where they are most needed and to better schedule workload over time. Since 1993, the watershed approach management model has provided a consistent and sequential internal structure for improving water quality, it is nationally recognized, and it is a prime example within EPA's Statewide Watershed Management Course as a planning and priority setting system.

The watershed approach synchronizes water quality monitoring, inspections and permitting and supports water protection activities on a geographic basis. It is a coordinated and integrated method to link science, permits, and other water pollution control and prevention activities to meet state water quality standards. As a management tool, the watershed approach focuses resources by matrixing staff through time into a variety of tasks and areas of the state. Each step of the process addresses specific evaluation, planning, and implementation needs. A strong public involvement process insures that the state continues to support and validate local watershed efforts. Local priorities strongly influence state planning and grant/loan funding priorities.

The State of Washington has been divided into 23 water quality management areas (WQMA's). Ecology has four regional offices located throughout the state. Each region has approximately five WQMA's with its boundaries with the exception of Eastern Regional Office has eight WQMA (total is 23). The WQMA's have been named and an identified staff "lead" has been assigned to coordinate watershed processes and activities within the area (see attached map).

Other water quality technicians and research staff are also targeted to these 23 WQMA's across the state. Point source permits for municipal and industrial facilities are scheduled within individual watersheds to be issued during the same year to ensure equity, consistency, and predictability (see attached schedule). Nonpoint source pollution controls along with technical and financial assistance programs are being integrated to complete the comprehensive system.

Five Step—Five Year Cycle

Each year, approximately four or five WQMAs are scheduled into a cycle. Within each cycle, there are five steps with each step consuming one year. The steps are:

- Year 1: SCOPING: Identify and prioritize known and suspected water quality issues within the WQMA by assembling input from extensive community involvement and internal Ecology staff. Produce a Needs Assessment.
- Year 2/3: DATA COLLECTION/ANALYSIS: Conduct water quality TMDL's, monitoring, special studies, class II inspections and general research to discern which of the issues identified in scoping are in fact problems.
- Year 4: TECHNICAL REPORT: Develop a report in coordination with the community that

addresses the problems identified above and other areas of concern- Also, outline strategies a&management activities needed to reissue **permits,** to form partnerships, **and** to solidify **nonpoint partnerships with** grants/loans.

- Year 5: IMPLEMENTATION: Issue/reissue waste water discharge **permits** arid work with local programs and partners to implement **nonpoint** pollution prevention and control activities that respond to priority water quality problems.

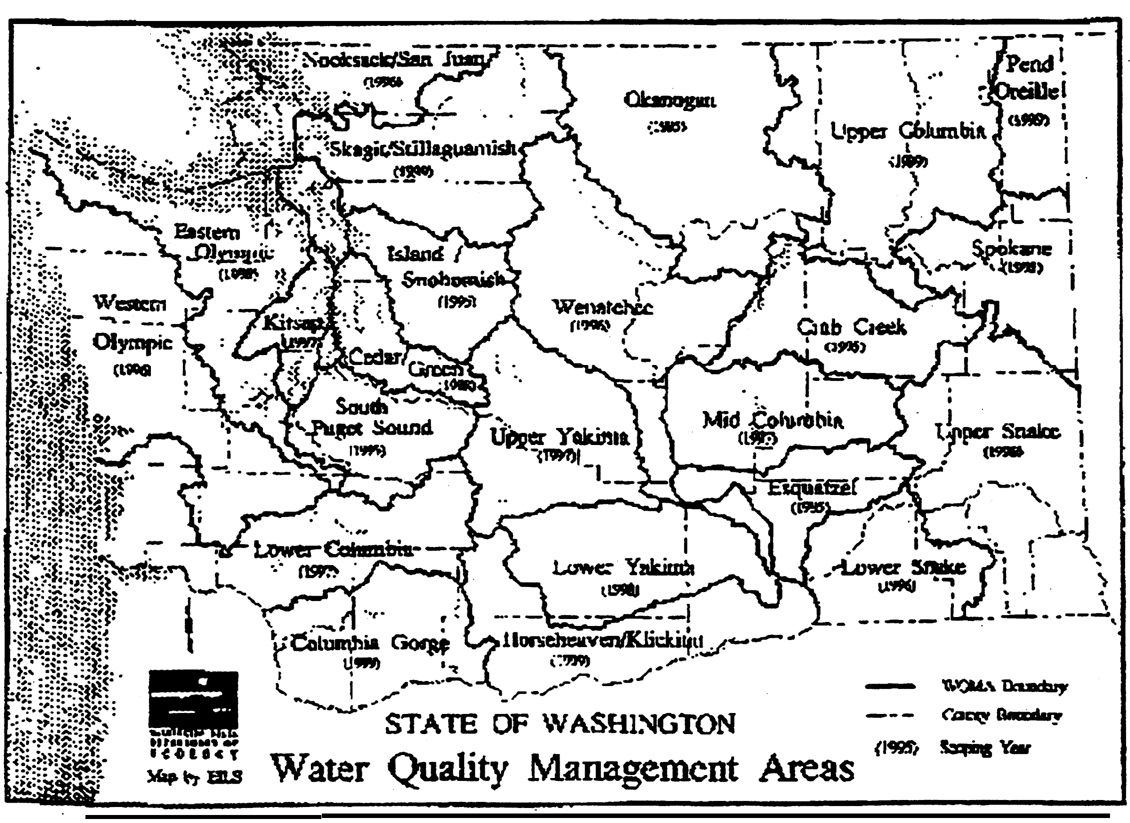
Approximately five WQMA's are scheduled each year to enter the process. The attached schedule shows the WQMA' **names** in the left-hand column organized into year **groups.** These groups are moved through the five step, five year process outlined above. In this way, the entire state **will** be covered within a period of five years. It is **important** to ***note that*** statewide coverage is ensured by scheduling WQMA's rather than prioritizing **them.** Scheduling avoids **the** ***priority trap, that is, placing all assets into one area only to find too much work leading to excluding*** **other** ***areas for treatment.***

The above process will be repeated on a five-year ***rotating*** cycle. By focusing on smaller geographical areas, Ecology closely scrutinize the sources and effects of pollution within each watershed **(WQMA) and can take** ***positive*** action to dramatically improve the water **quality** over time.

Unlike permitting which is mostly a scheduling effort, **nonpoint** problems must be addressed through cooperative relationships with local partners. In order to facilitate these activities, issues must be targeted, partners identified and cultivated, and funding sources must be coordinated and focused to address mutually agreed upon priority needs. Financial support systems are key and critical to a strong **nonpoint** effort. **In** its third year, the watershed approach model is now ready to create, innovate, and incorporate funding frameworks.

Lessons Learned to Date

- Targeting issues for treatment each cycle provides focus.
- Building relationships with partners is essential to **nonpoint** progress.
- Help and facilitate those who want to help themselves.
- Watershed teams are key to obtaining comprehensive information.
- Ecology staff act as brokers to **facilitate** multiple activities.
- Community involvement is essential for **continued** improvement.

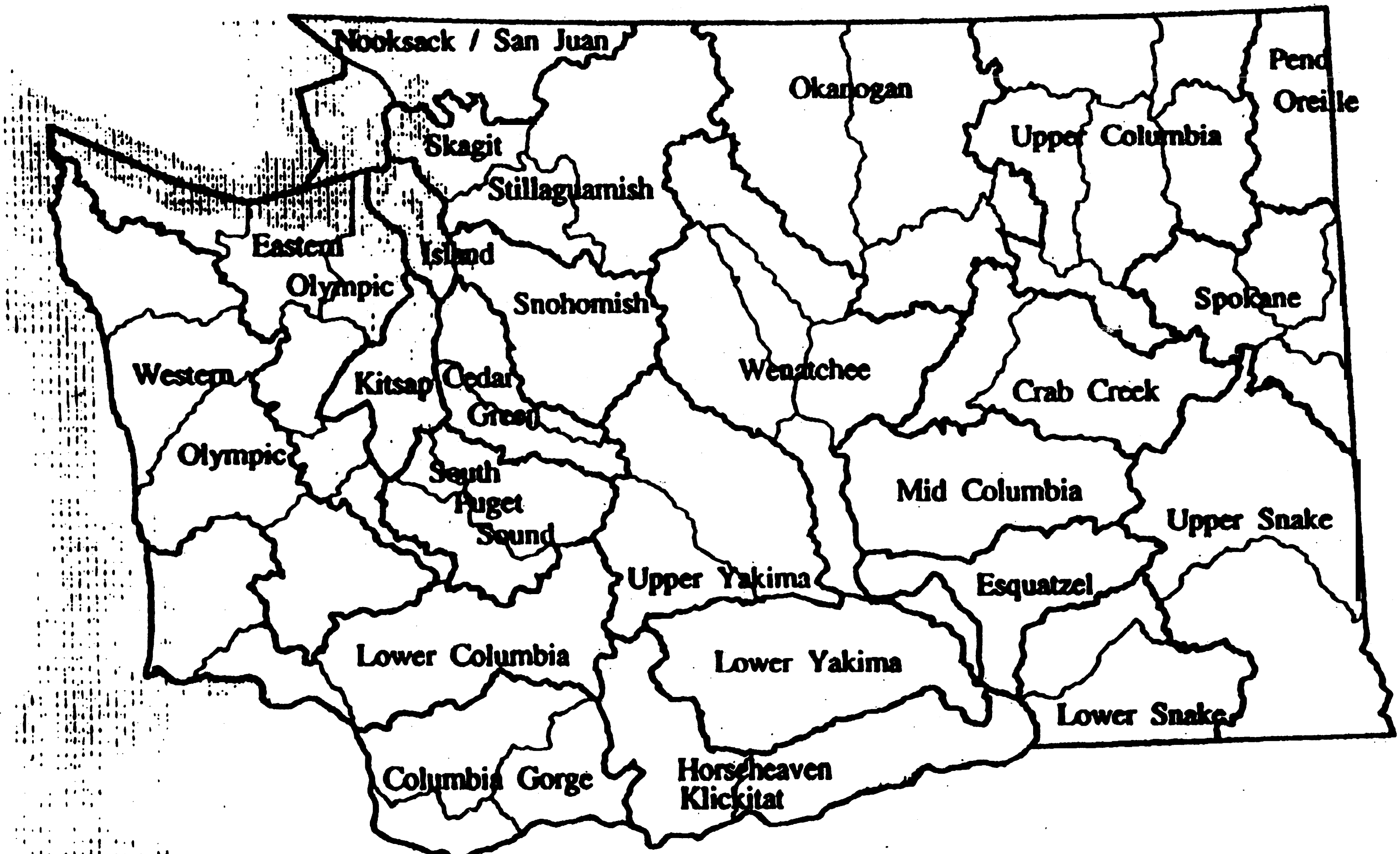


Watershed Approach to Water Quality Management

Activities Schedule for Watersheds Under S-year Cycle (lower case letters denote transition activities)								
	State Fiscal Year (July 1 through June 30)							
Water Quality Management Areas	FY94	FY95	FY96	FY97	FY98	FY99	FY01	FY02
Skagit/Stillaguamish, Columbia Gorge, Horse-heaven/Klickitat, Upper Columbia, Pend Oreille	S	D	A	R	I	S	D	A
Island/Snohomish, South Puget Sound, Okanogan, Crab Creek, Esquatzel		S	D	A	R	I	S	D
Nooksack/San Juan, Western Olympic, Wenatchee, Upper Snake, Lower Snake			S	D	A	R	I	S
Kitsap, Lower Columbia, Upper Yakima, Mid Columbia				S	D	A	R	I
Cedar/Green, Eastern Olympic, Lower Yakima, Spokane					S	D	A	R

I = Permits Issued; Other Actions Started
S = Scoping
D = Data Collection
A = Data Analysis
R = Technical Report

. Water Quality Management Areas

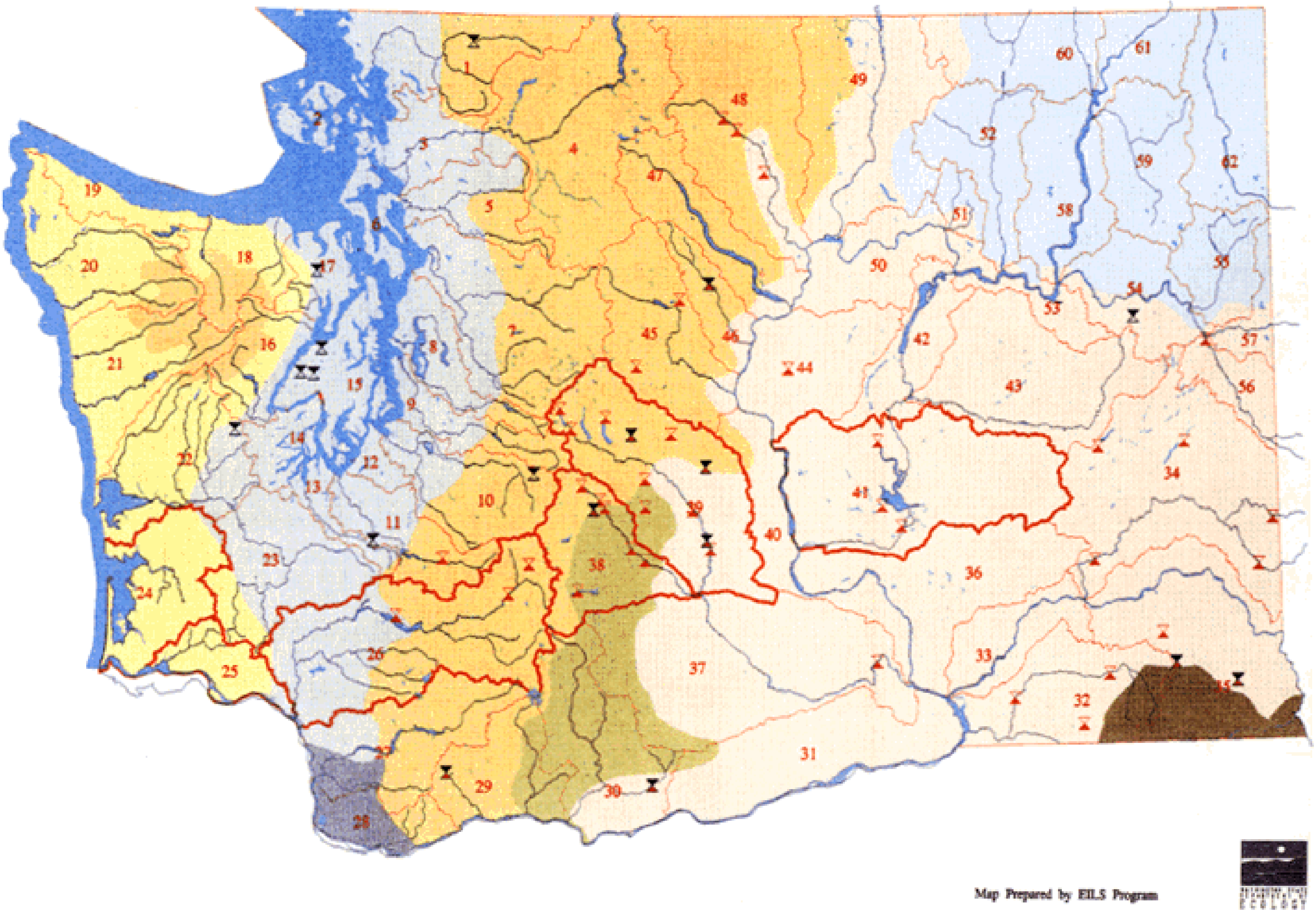


Department of Ecology, 1994

APPENDIX B

Site Locations of Biological Assessments in Washington State

Ambient Biological Assessment Sites: 1991 - 1993



Legend

Major rivers

WRIA boundaries

Water Quality Management Areas (FY96 Permits)

1991 T/F/W Program Sites

1993 Ambient Program Monitoring Sites

Ecoregions of Washington

Coastal Range

Puget Lowland

Willamette Valley

Cascades

Eastern Cascades Slopes & Foothills

Columbia Basin

Northern Rockies

Blue Mountains

Water Resource Inventory Areas

No.	Name	No.	Name
1	Nooksack	32	Walla Walla
2	San Juan	33	Lower Snake
3	Lower Skagit-Samish	34	Palouse
4	Upper Skagit	35	Middle Snake
5	Stillaguamish	36	Esquatzel Coulee
6	Island	37	Lower Yakima
7	Snohomish	38	Naches
8	Cedar-Sammamish	39	Upper Yakima
9	Duwamish-Green	40	Alkali-Squilchuck
10	Puyallup-White	41	Lower Crab
11	Nisqually	42	Grand Coulee
12	Chambers-Clover	43	Upper Crab-Wilson
13	Deschutes	44	Moses Coulee
14	Kennedy-Goldsborough	45	Wenatchee
15	Kitsap	46	Entiat
16	Skokomish-Dosewallips	47	Chelan
17	Quilcene-Snow	48	Methow
18	Elwha-Dungeness	49	Okanogan
19	Lyre-Hoko	50	Foster
20	Soleduck-Hoh	51	Nespelem
21	Queets-Quinault	52	Sanpoil
22	Lower Chehalis	53	Lower Lake Roosevelt
23	Upper Chehalis	54	Lower Spokane
24	Willapa	55	Little Spokane
25	Grays-Elokoman	56	Hangman
26	Cowlitz	57	Middle Spokane
27	Lewis	58	Middle Lake Roosevelt
28	Salmon-Washougal	59	Colville
29	Wind-White Salmon	60	Kettle
30	Klickitat	61	Upper Lake Roosevelt
31	Rock-Glade	62	Pend Oreille

SOURCE: Chapter 173-500 Washington Administrative Code

Biological Assessment Survey Sites for Summer 1993
Washington State Department of Ecology
Ambient Monitoring Section

Site	Drainage	WRIA	Ecoregion	Land Use(s)	Site Description	Gazetteer Page
American River	Naches	38	Cascades	Reference	large stream	p. 49
Little Naches River	Naches	38	Cascades	Forest practice	medium stream	pp. 49 & 65
Quartz Creek	Naches	38	Cascades	Relatively undisturbed	minimal forest practice	p. 65
Bear Creek	Naches	38	Cascades	Intact riparian zone	below FR 19/small stream	p. 65
Naches River	Naches	38	E. Cascades	Cumulative-agr. &forest.	large stream	p. 49
Indian Creek	Naches	38	Cascades	Reference	at Highway 12/medium stream	p. 49
Rattlesnake Creek	Naches	38	E. Cascades	Forest practices	at Nile Rd. Crossing/small stream	p. 50
M.F. Teanaway River	Upper Yakima	39	Cascades	Reference	medium stream	p. 66
Gold Creek	Upper Yakima	39	Cascades	Reference	medium stream	p. 65
Yakima River	Upper Yakima	39	Cascades	Regulated flow/forestry	mainstem above Cle Elum/lg. stream	p. 65
Yakima River	Upper Yakima	39	Columbia Basin	Irrigation return flow	mainstem near Ellensburg/lg. stream	p. 51
Taneum Creek	Upper Yakima	39	Cascades	Forest practices	medium stream	p. 66
Naneum Creek	Upper Yakima	39	Casc./Col. Basin	Reference/Forest Practice	medium stream	p. 67
Umtanum Creek	Upper Yakima	39	Columbia Basin	Reference	small stream	p. 51
Squaw Creek	Upper Yakima	39	Columbia Basin	Light grazing	small stream	p. 51
Cle Elum River	Upper Yakima	39	Cascades	Forest practices	above Lake Cle Elum/lg. stream	p. 65
S.F. Manastash Creek	Upper Yakima	39	E. Cascades	Forest practices	medium stream	p. 50
Box Canyon Creek	Upper Yakima	39	Cascades	Reference	FR 49; Kachess L. Rd./ med. stream	p. 65
Swauk Creek	Upper Yakima	39	Cascades	Utility/Forest practices	Highway 97 at Mineral Springs/sm. strm.	p. 66
Lower Crab Creek	Lower Crab	41	Columbia Basin	Agriculture/crops	at McManamon Rd./medium stream	p. 53
Sand Dune Creek	Lower Crab	41	Columbia Basin	Reference	at end of "C" SE crossing/medium stream	p. 53
Rocky Ford Creek	Lower Crab	41	Columbia Basin	Reference	protected riparian/ medium stream	p. 69
Ohanapecosh River	Cowlitz	26	Cascades	Reference	at Highway 123/ large stream	p. 48
Butler Creek	Cowlitz	26	Cascades	Channelized Banks	FR 5290 near Packwood/med. stream	p. 48
Simmons Creek	Cowlitz	26	Cascades	Old Second Growth	Peterman Hill Rd. nr Morton/small stream	p. 47
Elbe Creek	Nisqually		Cascades	Old Second Growth	at Highway 706 nr Ashford/small stream	p. 47
Tucannon River	Middle Snake	35	Columbia Basin	Grazing	Highway 126 nr. Mareago/med. stream	p. 42
Cummings Creek	Middle Snake	35	Columbia Basin	Reference	small stream	p. 42
N.F. Asotin Creek	Middle Snake	35	Columbia Basin	Reference	medium stream	p. 43

Biological Assessment Survey Sites for Summer 1993 Washington State Department of Ecology Ambient Monitoring Section						
Site	**Drainage**	**WRIA**	**Ecoregion**	**Land Use(s)**	**Site Description**	**Gazetteer Page**
Little Klickitat River	Klickitat	30	Columbia Basin	Reference	light grazing/medium stream	p. 26
S. Fork Crab Creek	Upper Crab-Wilson	43	Columbia Basin	Reference	Marcellus Rd. Crossing/ small stream	p. 71
Middle Foster Creek	Foster	50	Columbia Basin	Dryland wheat	at Mansfield Rd./ small stream	p. 84
Douglas Creek	Moses Coulee	44	Columbia Basin	Dryland wheat/grazing	at Alstown/small stream	p. 84
Hangman Creek	Hangman	56	Columbia Basin	Suburban/grazing	near mouth/medium stream	p.73
Trapper Creek	Wind-White Salmon	29	Cascades	Reference	FR 5401/medium stream	p. 23
Jack Creek	Wenatchee	45	Cascades	Reference	FR 7600/large stream	p. 82
Chiwawa River	Wenatchee	45	Cascades	Moderate forest practices	large stream	p. 82
Entiat River	Entiat	46	Cascades	Reference	Entiat River Rd./large stream	p. 83
Methow River	Methow	48	Cascades	Recreation	at Mazama / lg. stream	p. 113
Methow River	Methow	48	Cascades	Light Grazing	on Highway 20 at Goat Cr. Rd./lg. stream	p. 113
Twisp River	Methow	48	Columbia Basin	Forest Practices	at Poorman Cr. Rd./large stream	p. 99
Mill Creek	Walla Walla	32	Columbia Basin	Grazing/wheat	at Five Mile Rd. nr Harbert/med. stream	p. 41
Touchet River	Walla Walla	32	Columbia Basin	Grazing/crops	L&C Trail St. Park Hwy. 12/med. stream	p. 41
Touchet River	Walla Walla	32	Columbia Basin	Wheat/grazing	Touchet N. Rd. from Highway 124/med.	p. 40
Yakima River	Lower Yakima	37	Columbia Basin	Cumulative Agr./Irrigation	Horn Rapids Co. Park/lg. stream	p. 39
S. Fork Palouse River	Palouse	34	Columbia Basin	Reference	Wheat and suburban/small stream	p. 57
Palouse River	Palouse	34	Columbia Basin	Dryland wheat	at Palouse/medium stream	p. 57
Palouse River	Palouse	34	Columbia Basin	Irrigated wheat/grazing	at Hooper/large stream	p. 55
Pine Creek	Palouse	34	Columbia Basin	Grazing/wheat	Hole-in-the-Ground Rd./medium stream	p. 72
Cow Creek	Palouse	34	Columbia Basin	Wildlife Reserve	at Danekas Rd./small stream	p. 71

note: shaded rows indicate streams that were not surveyed during summer 1993.

Gazetteer Page (DeLorme, 1988)

APPENDIX C

Field Forms for Chemical and Physical Habitat Assessments

Waterbody Name: ______________________

Location/Station #: ______________________

Major Basin: ______________________

Dominant Land Use: ______________________

Date/Time: ______________________

Weather: ______________________

Latitude/Longitude: ______________________

Investigators: ______________________

SURFACE WATER INFORMATION			
Parameters	**Measurement (Qualifiers)**		
Temperature			
pH		Calibration or Calibration Check:	
Conductivity			
Dissolved Oxygen Sample Time:	Bottle no.	mL of titrant	Correction factor
Qualitative Observations			
Water Clarity			
Water Odors			
Sediment Odors			
Surface Films			

Field Notes:	
Photograph:	
Photograph:	

Qualitative Habitat Assessment Survey - Visual Analysis
Riffle/Run Prevalence

Site Name:	Site No:	Date:	Evaluator Initial:	
Habitat Parameter	**Optimal**	**Sub-Optimal**	**Marginal**	**Poor**
1. Substrate-Percent Fines (fraction < 6.35mm)	< 10% (16-20)	10 - 20% (11-15)	20 - 50% (6-10)	> 50% (0-5)
2. Instream Cover (cobble gravel, large woody debris, undercut banks, macrophytes)	> 50% (16-20)	30 - 50% (11-15)	10 - 30% (6-10)	< 10% (0-5)
3. Embeddedness (Riffle) (gravel, cobble, boulder particles)	0 - 25% (16-20)	25 - 50% (11-15)	50 - 75% (6-10)	> 75% (0-5)
4. Velocity/Depth	<u>all habitats</u>: i)slow/deep ii)slow/shallow iii)fast/deep iv)fast/shallow (16-20)	3 of 4 (11-15)	2 of 4 (6-10)	1 of 4 (0-5)
5. Channel Shape	trapezoidal (11-15)	rectangular (6-10)		inverse trapezoidal (0-5)
6. Pool/Riffle Ratio (distance between riffles/stream width)	5 - 7 (frequent sequence) (12-15)	7 - 15 (less frequent) (8-11)	15 - 25 (Infrequent riffle) (4-7)	> 25 (homogeneous) (0-3)
7. Width to Depth Ratio (wetted width/depth)	< 7 (12- 15)	8 - 15 (8-11)	15 - 25 (4-7)	> 25 (0-3)
8. Bank Vegetation (streambank coverage)	> 90% (9-10)	70 - 89% (6-8)	50 - 79% (3-5)	< 50% (0-2)
9. Lower Bank Stability (evidence of erosion)	<u>Stable</u> (9-10)	<u>Little Erosion</u> (6-8)	<u>Mod. Erosion</u> (3-5)	<u>Unstable</u> (0-2)
10. Disruptive Pressures (evidence of vegetation disruption on streambanks)	<u>Minimal</u> (all remains) (9-10)	<u>Evident</u> (60-90%) (6-8)	<u>Obvious</u> (30-60%) (3-5)	<u>High</u> (< 30%) (0-2)
11. Zone of Influence (width of riparian zone)	≥4 x BFW (BFW=Bankfull Width) (9-10)	≥2 & <4 (6-8)	≥1 & <2 (3-5)	<u>little</u> or <u>none</u> (0-2)
12. Successional Stage (forested sites only)	old-growth (9-10)	young (6-8)	pole sapplings (3-5)	seedlings/ clearcut (0-2)

Valley Segment Type	
Valley Bottom Slope	
Sideslope Gradient	
Valley Bottom Width	
Channel Pattern	
Adjacent Geomorphic Surfaces	

Waterbody Name: ________________

Location/Station #: ________________

Major Basin: ________________

Dominant Land Use: ________________

Date/Time: ________________

Weather: ________________

Latitude/Longitude: ________________

Investigators: ________________

Description of Valley Segment Types:

VALLEY SEGMENT TYPE	BOTTOM SLOPE	SIDESLOPE GRADIENT	VALLEY BOTTOM WIDTH	CHANNEL PATTERN	GEOMORPHIC SURFACES
A1: Estuarine Delta	< 1%	< 5%	>5 x active channel width	unconstrained, multiple	estuarine marsh, marine terrace
A2: Beach and Dune Flats	< or = 2%	< 5%	=>1 x active channel widt	unconstrained, multiple	sand dunes, marine terrace
B1: Wide, Alluviated Lowland Plains	< or = 1%	flat	>5 x active channel width	unconstrained, meandered	wide floodplains, marine terraces
B2: Wide, Alluviated Valley Floor	< or = 2%	> or = 10%	>5 x active channel width	unconstrained, meandered	wide floodplains, glacial outwash
B3: Alluvial Fan	1% to 3%	< 10%	>3 x active channel width	unconstrained, meandered	alluvial fans, wide floodplains
C1: Rolling Plains and Plateau	< 2%	< 10%	1-2x active channel width	meandered	marine terraces, volcanic flows
C2: Moderate Slope Bound Valley	2% to 4%	10% to 30%	1-2x active channel width	constrained, straight	low, moderate gradient hillslopes
C3: Moderate Gradient Footslope	2% to 4%	10% to 30%	1-2x active channel width	constrained, straight	low, moderate gradient hillslopes
C4: Alluviated, Moderate Slope Bound Valley	< or = 2%	< 10% up to 30%	2-4x active channel width	constrained, meandered	wide floodplain, alluvial terrace
D1: Incised, Moderate Gradient Channel Valle	2% to 6%	10-30%, increasing >30%	1-2x active channel width	moderate constraint, straight	unconsolidated glacial till
D2: Incised, High Channel Gradient Valley	6% to 9%	10-30%, increasing >30%	1-2x active channel width	boulder constrained, stairstepp	unconsolidated glacial till
E1: V-shaped, Moderate Channel Gradient Vall	2% to 6%	>30%, often >50%	1-2x active channel width	bedrock, boulder (be/bo) constr	steep, competent hillslopes
E2: V-shaped, Steep Channel Gradient Valley	6% to 11%	>30%, often >50%	= active channel width	(be, bo) constrained, stairstep	steep, competent hillslopes
E3: Alluviated Mountain Valley	< or = 3%	< or = 5%, increases to	2-4x active channel width	unconstrained, meander within s	wide, active floodplain
F1: U-shaped Trough	< or = 2%	0-10%, increases to >30	>4 x active channel width	unconstrained, meandered	low gradient, active floodplains
F2: U-shaped, Active Glacial Outwash Valley	1% to 7%	<5%, increases to >30%	1-2x active channel width	meandered and braided	active glacial outwash
G1: Moderate Gradient, Mountain Slope/Headwa	3% to 7%	10-30%, gradual increas	= active channel width	constrained, straight, stairste	moderate-steep hillslopes
G2: High Gradient, Mountain Slope/Headwall	8% to 20%	> 30%	= active channel width	(be, bo) constrained; stairstep	steep hillslopes
G3: Very High Gradient, Mountain Slope/Headw	> 20%	> 30%	= active channel width	(be, bo) constrained; stairstep	steep hillslopes

Compendium of Valley Segment characteristics outlined by Cupp (1989)

STREAM REACH PROFILE							
Transect	Wetted Width (riffles)	Bankfull Width (riffles)	Maximum Depth (riffles)	Residual Pool Depth (Dp-Dc=RPD)			Stream Gradient (Clinometer)
				Dp	Dc	RPD	
Riffle 1							
Riffle 2							
Riffle 3							
Riffle 4							

STREAM DISCHARGE					
Observation (Circle units)	Width (m or ft)	Depth (m or ft)	Velocity (m/s or ft /s)	Flag	Comments
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Residual Pool Depth: Dp=maximum depth of pool, Dc=depth at pool crest (or tailout), RPD=residual pool depth

SUBSTRATE MEASUREMENTS		
Substrate Parameter	**Transect 1 - Riffle (replicates)**	
Depth (m)		
Size Class (# intersections)		
Bedrock (smooth)		
Bedrock (rough)		
Boulder (250 to 4000 mm)		
Cobble (64 to 250 mm)		
Coarse Gravel (16 to 64 mm)		
Fine Gravel (2 to 16 mm)		
Sand (0.06 to 2 mm)		
Silt/Clay/Muck (not gritty)		
Wood (any size)		
Other (comment)		

SUBSTRATE MEASURMENTS		
Substrate Parameter	**Transect 2 - Riffle (replicates)**	
Depth (m)		
Size Class (# intersections)		
Bedrock (smooth)		
Bedrock (rough)		
Boulder (250 to 4000 mm)		
Cobble (64 to 250 mm)		
Coarse Gravel (16 to 64 mm)		
Fine Gravel (2 to 16 mm)		
Sand (0.06 to 2 mm)		
Silt/Clay/Muck (not gritty)		
Wood (any size)		
Other (comment)		

Comments:

WOODY DEBRIS				
Diameter (cm)	Length (m)	Decay Class	% in Water	Structural Configuration

WOODY DEBRIS CODES	
Decay Class Codes	
1	Intact bark, twigs
2	Intact bark, no twigs
3	Partial bark, smooth wood
4	No bark; abrasion and dark colour; some holes
5	No bark; abrasion,dark colour; many holes and irregular shapes
Structural Configuration Codes	
S	Single
C	Clustered

SUBSTRATE EMBEDDEDNESS	
Depth (total) / Depth (embedded) (Circle: cm or in.)	Depth (total) / Depth (embedded) (Circle: cm or in.)
Transect 1	Transect 2

VISUAL RIPARIAN ESTIMATES				
Riparian Vegetation Cover	0 = Absent (riparian area within 10 m of the stream) 1 = Sparse (0-10%) 2 = Moderate (10-40%) 3 = Heavy (40-75%) 4 = Very Heavy (>75%)			
RIPARIAN VEGETATION		**Left Bank**	**Right Bank**	**Flag**
Canopy (> 5m high)				
Vegetation Type (D, C, M, or N)				
Big Trees Trunk > 0.3m DBH				
Small Trees Trunk < 0.3m DBH				
Understory (0.5m to 5m high)				
Vegetation Type (D, C, M, or N)				
Woody Shrubs and Saplings				
Non-woody herbs, grasses, and forbs				
Ground Cover (< 0.5m high)				
Woody shrubs and seedlings				
Non-woody herbs, grasses, and forbs				
Barren, bare dirt or duff				

CANOPY COVER MEASUREMENTS				
DENSIOMETER (no.; 17 maximum)				
Direction	**Riffle 1**	**Pool 1**	**Riffle 2**	**Pool 2**
Center (up)				
Center (down)				
Center (left)				
Center (right)				
Left Bank				
Right Bank				

HUMAN INFLUENCE		
O = not present B = on bank C = within 10m P = > 10m		
Disturbance	**Left Bank**	**Right Bank**
Dike/Riprap		
Buildings		
Pavement		
Road/Railroad		
Pipes (inlet/outlet)		
Landfill/Trash		
Park/Lawn		
Row Crops		
Pasture/Range		
Logging Operations		

D=Deciduous; C=Coniferous; M=Mixed; N=None

Equipment List for Biological Assessment Field Activities

Washington State Department of Ecology
Ambient Monitoring Section
Olympia, WA

Biological Surveys

Sampling nets (2) ____________
Ty-Wrap® Cable (20) ____________
Field Preservative (85% denatured ethanol)-5 gallons ____________
One liter Nalgene® containers (40) ____________
1/4 liter Nalgene® containers (40) ____________
One gallon Heavy Duty Ziploc® freezer bags (30 bags) ____________
Waders (hip) ____________
Waders (chest) ____________
Wader Repair Kit (1) ____________
Labels (water sample tags)-40 tags ____________
Sharpie® Markers (2) ____________
2 1/2 gallon buckets (2) ____________
Camera (1) ____________
Slide Film (2 rolls) ____________

Habitat Surveys

Habitat Survey forms for each site (10 sets) ____________
150 ft. Keson® Fiberglass Tape (1) ____________
Fibergalss Stadia Rod (1) ____________
Suunto Clinometer (1) ____________
Suunto Compass (1) ____________
Marsh-McBirney Flow Meter (1) ____________
Flow Rod (1) ____________
Substrate Grid (1) ____________
Plexiglass View Tube (1) ____________
Embeddedness Cable Circle (1) ____________
Densiometer (1) ____________
Solar Pathfinder (1) ____________
Magellan® GPS (1) ____________
"A Good Eye!" ____________

Equipment List for Biological Assessment Field Activities (Continued)

Water Quality Surveys

250 mL Nalgene® Water Collection Bottles (2)	________
Mercury Thermometers (2)	________
Orion pH Meter (1)	________
YSI Conductivity Meter (1)	________
Winkler Dissolved Oxygen Bottles/Tray (12 bottles)	________
De-ionized Water (2 1/2 gallons)	________
Field Notebook (2)	________
Buffer Solutions (pH 4, pH 7, pH 10)	________
10% Hydrochloric Acid (HCl) - 250 mL	________

Personal Gear

Elbow Length Insulated Gloves (1 pair)	________
Rain Gear (Jacket)	________
Leather Gloves (1 pair)	________
Field Vest (Orange)	________
Eyewash Kit	________

APPENDIX D

Data Management:
Biological Information and Habitat Variables

Biological Database

The following fields and their descriptions are included in the biological component of the summer 1993 database:

ECOREGION:	04 = Cascades 06 = Eastern Cascades Slopes and Foothills 07 = Columbia Basin
STATION:	alphanumeric field with a capacity of 20 characters
DAY:	two-digit number for day of month the sample was collected
MONTH:	two-digit number the month the sample was collected
YEAR:	four-digit number the year the sample was collected
SEASON:	alphanumeric field with a capacity of eight characters
CODE:	taxonomic identification code delineated in BIOS (U.S. EPA STORET database)
TAXONID:	lowest level of taxonomic identification for each entry (BIOS)
TAXON:	higher levels of taxonomic identification than the "ordinal" level (BIOS)
ORDER:	taxonomic category (BIOS)
FAMILY:	taxonomic category (BIOS)
GENUS:	taxonomic category (BIOS)
SPECIES:	taxonomic category (BIOS)
TIS:	taxonomic information source (literature citations)
CIC:	confidence identification code (known quality of identifications: A=99.9%, B=99%, C=90%, D=Unknown) (BIOS)
SAMPLE1:	abundance estimate for sample number 1
SSAMPLE1:	estimated abundance from sub-sample number 1

SAMPLE2:	abundance estimate for replicate sample
SSAMPLE2:	estimated abundance from replicate sub-sample
SAMPLE3:	abundance estimate for replicate sample
SSAMPLE3:	estimated abundance from replicate sub-sample
SAMPLE4:	abundance estimate for replicate sample
SSAMPLE4:	estimated abundance from replicate sub-sample
SAMPLE5:	abundance estimate for replicate sample
SSAMPLE5:	estimated abundance from replicate sub-sample
METHOD TYPE:	HESS = modified Hess Sampler SURBER = Surber Sampler KICK = stationary square kicknet DKICK = stationary D-frame kicknet TRAVKICK = travelling D-frame kicknet ROCK = multiple rock collection (usually three) PIBS = portable invertebrate box sampler ECKMAN = Eckman Grab PONAR = Ponar Grab BASKET = wire mesh rock basket (artificial sampler) TRAY = rock-filled trays (artificial sampler) MPLATE = multi-plate artificial sampler
SAMPLE AREA:	alphanumeric field that has an eight character capacity (examples of common notation: 1.0 m^2, 1.0 ft^2, 0.1 m^2, 0.5 m^2)
FFG:	functional feeding group classification of a taxon: SHRED = Shredders (live plant or dead plant) CFILT = Collector-filterers (suspension feeders) CGATH = Collector-gatherers (deposit feeders) SCRAP = Scrapers (grazers) PREDT = Predators (engulfers) PIERC = Piercers (plant or animal)
TV:	impact tolerance value of a taxon that is denoted by Hilsenhoff (1977, 1982, 1987) and Plafkin *et al*. (1989).
STUDY:	defines the type of site impact or anthropogenic influence, if any: REF = Reference AGR = Agricultural Practices

- AGR-PAS = Animal pasturing
- AGR-CRP=Crop Production
- AGR-PST=Pesticide use
- AGR-HRB=Herbicide use

FOR = Forest Practices

- FOR-RDC=Road Construction
- FOR-CLC=Clear-cutting
- FOR-RMZ=Riparian Management Zone
- FOR-PST=Pesticide use
- FOR-HRB=Herbicide use

MIN = Mining

- MIN-OPN=Open Pit
- MIN-UDG=Underground

URB = Urban

- URB-SBP=Suburban/Park
- URB-STW=Stormwater

WTP = Wastewater Treatment Receiving Water

- WTP-IND=Industrial
- WTP-MCP=Municipal

Habitat Database

Physical and chemical information recorded for each site during field information collection is described in field forms located in Appendix C. The following fields and their descriptions are included in the habitat evaluation component of the summer 1993 database:

ECOREGION:	04 = Cascades 06 = Eastern Cascades Slopes and Foothills 07 = Columbia Basin
STATION:	alphanumeric field with a capacity of 20 characters
DAY:	two-digit number for day of month the sample was collected
MONTH:	two-digit number the month the sample was collected
YEAR:	four-digit number the year the sample was collected
SEASON:	alphanumeric field with a capacity of eight characters
LAT.DEGREES:	Latitude (degrees North)
LONG.DEGREES:	Longitude (degrees West)
LAT.MINUTES:	Latitude Minutes (6-digits)
LONG.MINUTES:	Longitude Minutes (6-digits)
VALLEY TYPE:	Valley Segment Classification Type (Cupp, 1989)
CHANNEL CLASSIFICATION:	Reach-level stream classification (Montgomery and Buffington, 1993)
WETTED WIDTH:	4 measurements taken (2 riffle, 2 depositional)
BANKFULL WIDTH:	4 measurements taken (2 riffle, 2 depositional)
MAXIMUM DEPTH:	4 measurements taken (2 riffle, 2 depositional)
RESIDUAL POOL DEPTH:	2 measurements taken at depositional areas
STREAM DISCHARGE:	measured at lower stream site boundary
STREAM GRADIENT:	2 sitings per stream site

SUBSTRATE SIZE: dominant and subdominant size classes

WOODY DEBRIS: dominant and subdominant size classes

SUBSTRATE EMBEDDEDNESS: mean ± standard deviation

RIPARIAN ESTIMATE: overhead, understory, ground cover (dominant density)

CANOPY COVER: densimeter measurements for riffle and depositional

HUMAN INFLUENCE: dominant influence nearest the stream (left and right banks)

LAND OWNERSHIP: PRI = Private
DNR = Department of Natural Resources
WDW = Washington Department of Wildlife
USFS = United States Forest Service